Response to Office Action of 03/03/2004

Modify Claim 21 as follows:

21. A sensor for measuring a vector component of heat flux comprising:
a thin flat substrate plate of thermally conducting, electrically insulating material;
a thin film thermopile deposited on a surface of said substrate plate ~~with the axis of said thermopile aligned with said vector~~; and
electrical connections on said thin film thermopile for measuring its voltage, wherein said vector component of heat flux is measured on the axis of said thermopile..

Modify Claim 28 as follows:

28. The sensor of claim 24 in which said slot is formed in ~~the~~ an end of said plug.

Modify Claim 29 as follows:

29.The sensor of claim 25 in which said slot is formed in ~~the~~ an end of said plug.

Modify Claim 37 as follows:

37. The sensor of claim 35 in which said slot is formed in ~~the~~ an end of said plug.

Modify Claim 38 as follows:

38. The sensor of claim 36 in which said slot is formed in ~~the~~ an end of said plug.

Listing of all claims per revised 37 CFR §1.121

1-20. (cancelled)

21. (currently amended) A sensor for measuring a vector component of heat flux comprising:
a thin flat substrate plate of thermally conducting, electrically insulating material;
a thin film thermopile deposited on a surface of said substrate plate ~~with the axis of said thermopile aligned with said vector~~; and
electrical connections on said thin film thermopile for measuring its voltage, wherein said vector component of heat fllux is measured on the axis of said thermopile.

22. The sensor of Claim 21 further comprising a thin flat cover plate of thermally conducting, electrically insulating material covering said thermopile on said substrate plate.

23. The sensor of claim 22 further comprising a solid body; and
means for holding together and imbedding said substrate plate and said cover plate within said solid body.

24. The sensor of claim 23 in which said means for holding together and imbedding said substrate plate and said cover plate within said solid body comprises a threaded plug having a slot for holding said substrate plate and said cover plate together.

25. The sensor of claim 23 in which said means for holding together and imbedding said substrate plate and said cover plate within said solid body comprises a cylindrical plug having a slot for holding said substrate plate and said cover plate together.

26. The sensor of claim 24 in which said slot is formed in the side of said plug.

27. The sensor of claim 25 in which said slot is formed in the side of said plug.

28. (currently amended) The sensor of claim 24 in which said slot is formed in ~~the~~ an end of said plug.

29. (currently amended) The sensor of claim 25 in which said slot is formed in ~~the~~ an end of said plug.

30. The sensor of claim 23 in which the materials of said substrate plate and said cover plate have thermal properties closely matching those of said solid body.

31. The sensor of claim 23 in which the material of said substrate plate and said cover plate is aluminum nitride.

32. The sensor of claim 23 in which said substrate plate and said cover plate are made of metal

having a thin coating of electrical insulating material over at least a part of their surfaces.

33. A sensor for measuring heat flux along an axis within a solid body comprising:
a thin flat substrate plate of thermally conducting, electrically insulating material;
a thin film thermopile deposited on a surface of said substrate plate with hot and cold junction pairs of said thermopile aligned with said axis;
electrical connections on said thin film thermopile for measuring its voltage; and
means for imbedding said substrate plate within said solid body.

34. The sensor of claim 33 further comprising a cover plate of thermally conducting, electrically insulating material for covering said thermopile on said substrate plate.

35. The sensor of claim 34 in which said means for imbedding said substrate plate within said body comprise:
a threaded plug having a slot for holding said substrate plate; and
a threaded hole in said solid body.

36. The sensor of claim 34 in which said means for imbedding said substrate plate within said body comprise:
a cylindrical plug having a slot for holding said substrate plate; and
a hole in said solid body with diameter suitable for a press fit of said plug into said hole in said solid body.

37. (currently amended) The sensor of claim 35 in which said slot is formed in ~~the~~ <u>an</u> end of said plug.

38. (currently amended) The sensor of claim 36 in which said slot is formed in ~~the~~ <u>an</u> end of said plug.

39. The sensor of claim 35 in which said slot is formed in the side of said plug.

40. The sensor of claim 36 in which said slot is formed in the side of said plug.

41. The sensor of claim 33 in which the material of said substrate plate has thermal properties closely matching those of said solid body.

42. The sensor of claim 34 in which the materials of said substrate plate and said cover plate have thermal properties closely matching those of said solid body.

Discussion

Examiner rejected Claims 21, 28, 29, 37 and 38 for the following informalities:

a. In Claim 21, Line 3: "the axis of said thermopile" lacks antecedent basis.

b. In Claim 21, Line 4: "said vector" lacks antecedent basis.

c. In Claim 28, Line 1: "the end of said plug" lacks antecedent basis, since it is considered that there are two ends of a cylindrical plug.

d. In each of Claims 29, 37 and 38 in Line 1: "the end of said plug" lacks antecedent basis.

Applicant has deleted a phrase and added language to Claim 21 that more distinctly and particularly identifies the invention. The deleted phrase, "with the axis of said thermopile aligned with said vector," implied that the vector pre-exists the sensor, and the thermopile is lined up with it. The new phrase "wherein said vector component of heat flux is measured on the axis of said thermopile" more clearly describes the directivity of the sensor's response. This is Applicant's first opportunity to respond to Examiner's rejection of this claim.

Applicant appreciates examiner's suggestions for modification of Claims 21, 28, 29, 37 and 38 to provide antecedents where required

Examiner finally rejected Claims 21 and 22 under 35 U.S.C. 102(b) as being anticipated by SALLEE *et al* (U.S. Pat. No. 4,817,436, hereinafter SALLEE). Although none of the terms "thin film", "vector", "axis" or "component" appear in SALLEE, Examiner has chosen to interpret its operation using these terms. It is applicant's position that none of these terms applies to SALLEE, the function of SALLEE is entirely different from that of Applicant's invention, and therefore SALLEE does not anticipate Applicant's invention.

It is essential to understand how SALLEE works as a heat flux measuring instrument. Heat flowing orthogonally across the plane of the sensor, that is, from metal sheet 26 to thin metal sheet 20, is the quantity measured. The electrical signal representing this quantity is developed by a thermopile made up of "thermocouples disposed on either side of a heat-resistant insulating substrate", identified as 2 in the SALLEE drawings. Small local temperature differences are developed <u>in the plane of the sensor</u> by geometric asymmetries, which are in the form of zones 4 containing channels 16. Each thermocouple pair of the thermopile has a first element beneath the closed part of its corresponding zone 4 and a second element beneath the open part of its corresponding zone 4. Successive rows of the thermopile develop temperature differences in the opposite sense. This insures that the sensor will not be sensitive to heat flux in the plane of the substrate 2, but will respond only to temperature differences which are developed locally by the geometric asymmetries. This is distinct from Applicant's invention, which is designed to have

maximum sensitivity to heat flux in the plane of its substrate, and is insensitive to heat flux crossing the plane of its substrate orthogonally. Thus the two inventions measure heat flux in an entirely different manner.

The reason why SALLEE did not use the terms "vector", "axis" "or"component", is that he did not conceive of imbedding his sensor in a solid body for measurement of the vector component of heat flux within the body. Even if he had conceived of this use for it, the sensor described in his patent would be a very poor choice for such a measurement. Its thermal resistance would be far too great, and the flow of heat in the solid body would be severely distorted. SALLEE also did not conceive of the merits of using a thin film thermopile, producing negligible resistance to the flow of heat in all directions. Furthermore, SALLEE did not conceive of matching the thermal resistance of the sensor to that of surrounding material, in order to reduce distortion of the heat flux field to a minimum.

Another difference between SALLEE and applicant's invention is that Applicant's thermocouples are all on one side of the substrate 18, while the thermocouples of SALLEE are on opposite sides of his substrate 2. The SALLEE construction thus requires through holes, or "vias" in the substrate, with some means of connection through them. Applicant's sensor construction is much simpler, requiring no through holes or "vias". The relative simplicity of Applicant's invention may be better understood by comparing the fabrication processes for the two sensors.

Applicant's invention requires only two manufacturing steps; (1) deposition of the first thermocouple metal thin film pattern on the substrate surface, and (2) deposition of the second thermocouple metal thin film pattern, overlapping the first, on the substrate surface.

SALLEE requires nine manufacturing steps (quoting each step from the patent, Col. 4, Lines 24-57):
(1) applying on one face of said substrate a first continuous thin layer made of the first conductive or semi-conductive matter mentioned above, advantageously in the form of a sheet,
(2) applying on the other face of said substrate, opposite said first layer, a second continuous thin layer made of the fifth conductive or semi-conductive matter mentioned above, advantageously also in the form of a sheet,
(3) posing determined masks on said first and second layers coating the substrate, advantageously defining lines of attack of the layers;
(4) etching said layers by immersing the whole with the masks in an etching solution by the conventional engraving technique so as to etch the first and second layers along certain lines, thus defining in the first sheet the uninterrupted layer mentioned above and the first patterns mentioned above, and in the second sheet, the second patterns mentioned above,
(5) depositing by metallization the zones mentioned above made of a second conductive or semi-conductive matter on said uninterrupted thin layer, advantageously with the aid of masks,
(6) making the orifices and channels mentioned above, advantageously by chemical attack with masks;

(7) and depositing by metallization metal coatings inside the orifices mentioned above, advantageously also with use of masks,
(8) - - a sheet of insulating matter is applied on the face comprising the zones mentioned above, and then
(9) a conductive or semi-conductive sheet, preferably identical to the second sheet mentioned above, made of the fifth conductive or semi-conductive matter.

According to Examiner's rejection, SALLEE discloses "a thin film thermopile (comprising first pattern 8; Col. 5, Lines 31-50)". However, first pattern 8 is not a thermopile, but is connected by spot weld 12 to second pattern 10 to form a temperature measuring thermocouple. Neither first pattern 8 nor second pattern 10 is a thin film.

Examiner's rejection continues, "with the axis of the thermopile aligned with said vector". As pointed out earlier by Applicant, SALLEE's thermopile is specifically designed to be insensitive to heat flux in the plane of the sensor, and therefore has no axis. The sensor itself has no axis because metal layers 20 and 26 redistribute the measured heat flux over the entire surface of the substrate. This feature is described in SALLEE, Col. 3, Lines 57-61, "by the presence of the sheets of fifth conductive or semi-conductive matter and of sixth conductive or semi-conductive matter electrically insulated from the uninterrupted thin layer defining the thermal fluxmeter, the flux is uniformly distributed". Thus the response of the sensor to heat flux is non-directional, and there is no axis.

Examiner has finally rejected Claims 23-32 under U.S.C. 103(a) as being unpatentable over SALLEE and further in view of U.S. Pat. No. 4,904,091 (WARD). According to Examiner, SALLEE discloses or suggests a sensor for measuring a vector component of heat flux as claimed by Applicant in Claims 23, 25, 27, 29 and 30-32. Further regarding Claim 30 and 32, Examiner maintains that "SALLEE discloses or suggests the materials have thermal properties closely matching those of the solid body, the materials being copper, being a metal and further having a coating of electrical insulating material over at least a part of their surfaces as claimed by Applicant in Claims 30 and 32."

Applicant has studied SALLEE thoroughly, and finds no reference in this patent to (1) a vector component of heat flux (2), matching the thermal properties of materials, or (3) a solid body. In view of the absence of such references, and especially in view of the differences in intent and construction between SALLEE and Applicant's invention as pointed out above, Applicant finds no support for the obviousness rejection.

A person having ordinary skill in the design of heat flux sensors as exemplified by SALLEE, would not arrive at Applicant's invention by the ordinary process of engineering or design. . If Applicant were to approach the design of a heat flux vector measuring instrument, starting with the technology of SALLEE, the result would be a complex, multi-step process involving many different materials, not the simple two-step fabrication process of Applicant's invention.

SALLEE and others skilled in this art have taught that heat flux measurement is a scalar process in which the direction of heat flow is neither measurable nor of interest. Applicant's invention is the first example of a vector measurement in the art of heat flux measurement, a distinct departure from the teaching of all others who have worked in this field..

To quote Examiner, "- - it would have been obvious to one having ordinary skill in the art at the time the invention was made to provide the heat flux sensor of SALLEE with a means for imbedding comprising a threaded cylindrical plug 11, including a slot formed in the end and side of the plug as taught by WARD in order to benefit from avoiding undesirable protrusions beyond the test surface as taught by WARD." Indeed the SALLEE device could be imbedded in a solid by this means or another, but the result would be (1) a major distortion of the heat flux field by the voids and low thermal conductivity materials contained in SALLEE, and (2) no information about a vector component of heat flux in any axis. Any attempt to reduce the thermal non-uniformities produced by the SALLEE construction would diminish its sensitivity without providing any vector information.

The teaching of WARD, as exemplified by his Figures 1 and 2, would support the conclusion that the configuration of threaded bolt 12 on the opposite side of the solid body from the tip end 14 is not material to measurement accuracy. This is plainly not so. The protruding end of the bolt will have a dramatic effect on the heat transfer coefficient on that end, and on the temperature and heat flux at the tip end. It will distort the heat flux field within the solid body as well. The large bolt head illustrated in WARD will thus have a dramatic effect on any thermal measurements made at the tip end or in the solid body.

Examiner further states "Thus it would have been obvious to one of ordinary skill in the art to substitute aluminum nitride for the copper plate and cover material of SALLEE, when the sensor is modified as taught by WARD, because of its known electrically insulating properties in order to electrically insulate the substrate and also because of its high value of thermal conductivity making it an optimum material for a heat flux gage." Indeed, aluminum nitride could be substituted for the substrate of SALLEE, but that would not make it a vector sensor. As clearly described above, the basic construction of SALLEE does not create an axis for vector component measurements, and no substitution of materials will change SALLEE into a heat flux vector sensor.

Examiner finally rejects Claims 33-42 under 35 U.S.C. 103 (a) as being unpatentable over SALLEE in view of WARD. However, Examiner's recitation of the functions of the SALLEE device is entirely incorrect. As pointed out above, first pattern 8 is not a thermopile. This pattern is connected by spot weld 12 to second pattern 10 to form a temperature measuring thermocouple. Neither first pattern 8 nor second pattern 10 is a thin film, and the resulting combination does not measure heat flux. Also, hot 8 and cold 10 junction pairs are not aligned with the axis (postulated by examiner to be orthogonal to the substrate) because they are in the plane of the substrate.

Regarding Claim 34, Examiner's statement may be correct, but this detail of similarity in construction does not negate the novelty of applicant's invention.

Further regarding Claims 41 and 42, Examiner also errs in stating "SALLEE discloses or suggests the materials have thermal properties closely matching those of the solid body, - - " There is no mention of material thermal properties in the referenced patent, nor any mention of a solid body.

Examiner relies on WARD to show that it is known in the art to embed a sensor in a solid body using a cylindrical plug (Col. 2, lines 50-66). However, the purpose of such embedding, and the resulting measurements, are entirely different from those of Applicant's invention. In WARD the purpose of embedding the sensor is to facilitate an average temperature measurement at a point on the inner surface of the solid. Applicant's objective is to reduce the disturbance to heat flow through the solid so that an accurate measurement of the heat flux vector within the solid may be obtained.

According to WARD, "Threaded cylindrical receptacle 32 may be a pre-existing bored cylinder for other devices such as an ordinary heat flux gage"(Column 2, Line 65). Some examples of ordinary heat flux gages are Schmidt-Boelter gages (U.S. Patents 1,528,383 , 2,493.651 and 6,186,661), Vatell Corporation's Heat Flux Microsensors (U.S. Patent 4,779,994) and Gardon gages. Any of these sensors may be obtained from the manufacturer in a threaded or cylindrical housing, for through-hole mounting in a solid body. The purpose of this style of mounting is to measure heat flux at the inner surface of the solid. The amount of distortion of the heat flow field in the solid is significant and depends on sensor materials and design. Even though installed in this manner, none of the gages will measure the heat flux within the solid body